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(54) Preparation of symmetrical triglycerides aba

(57) The invention concerns an enzymatic preparation process for triglycerides of the ABA-type (A and B can be any fatty acid residue), wherein:

a) 2-monoglyceride is converted with a reactant providing fatty acid moieties A using a 1.3-specific enzyme, while controlling the water activity A_w to a value < 1.0.

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Description

Symmetrical triglycerides of the type ABA, wherein A and B both can be selected from saturated and unsaturated fatty acid residues are known compounds in the art. Typical examples of these triglycerides that are applied at industrial scale are OPO as human milk fat replacer, SOS as cocoa butter equivalent, C12C18C12- or C18C12C18-triglycerides as antiblooming agent or as structuring component in spreads. All these components are made so far by performing a chemical or enzymic esterification on an oil or a fraction thereof. However all these reactions resulted in products wherein the amount of B originally present in the 2-position of the triglyceride was decreased as a result of the esterification reaction.

Although JP 62/228290 (published Oct '87) discloses a method for the preparation of cocoa butter substituents, wherein in a first step a fat high in 2-oleic triglycerides is subjected to an enzymatic hydrolysis resulting in a product high in 2-monoglycerides, whereupon this product is resynthesised using a 1,3 specific lipase to a product rich in SOS type triglycerides, it can also be concluded from the results mentioned in this patent that the hydrolysis never was performed in such a way that the product obtained was a pure or nearly pure 2-oleic monoglyceride. From the example it can be concluded that starting from a palm fraction and using stearic acid for the resynthesis the product obtained contained appreciable amounts of triglycerides with palmitic in the 1,3 positions. This can only be explained by the fact that the hydrolysis never led to a product high in 2-oleic monoglyceride. This product must have contained appreciable amounts of partial glycerides also containing palmitic acid in it (such as the diglycerides PO or the P-monoglyceride),which upon further reaction might have isomerised. A confirmation herefore can also be found in the fact that the total of triglycerides POP + POS + SOS in the reaction product only adds up to about 80% sothat still
20% of other not identified impurities must have been present.
Above might be due to the fact that the hydrolysis is performed in the presence of excess of water.

We performed a study in order to find a process wherein an optimal use could be made of the amount of fatty acid B that was present in the starting material and in which the level of isomerisation was limited to the minimum. The process we found is based on the use of monoglycerides with a high level of 2-B-monoglyceride in esterification processes wherein we could avoid that the group B migrated over the glycerol backbone during the conversion of the 2-B-monoglyceride into triglycerides of the ABA type. This was highly unexpected because it is well documented in the prior art that partial glycerides including monoglycerides are easily isomerised during their conversion, in particular if the conversion is performed in the presence of water or traces of acid or base.

We further studied whether the type of support for the enzyme had an impact on the end product composition and whether the type of solvent would influence the product composition. We found that in all instances such an impact existed.

Therefore our invention concerns in the first instance a process for the preparation of triglycerides of the ABA type, wherein A = saturated or unsaturated or polyunsaturated fatty acid residue with 2-24 C atoms and B = saturated or unsaturated or polyunsaturated fatty acid residue, while A is not simultaneously identical with B in the same molecule by:
subjecting a compound with a high content of, preferably more than 80 % of, most preferably more than 90 % of 2-monoglyceride with a group B substituted at the 2 position to an enzymatic conversion with a reactant providing fatty acid moieties A using a 1,3-specific enzyme under conditions that control the water activity Aw to a value < 1.0, in particular 0.1-0.5.

Essential for the positive outcome are thus the availability of a monoglyceride with a high content of 2-B-monoglyceride and the conversion hereof with a 1,3 specific enzyme under well controlled conditions of water content. In particular the water that is formed during the conversion must be removed during the enzymatic conversion, so that the Aw value during the conversion is maintained at a value < 1.0, in particular between 0.1 and 0.5. Herefore the reaction can be performed in the presence of a water absorbent such as a molecular sieve or the water can be removed by using reduced pressure and elevated temperature during the conversion.
In above process all known 1,3 specific enzymes can be applied. However we have a preference for the use of enzymes selected from the group consisting of Rhizopus delemar, Rhizopus javanicus and Rhizomucor miehei. The best results were obtained if the enzymes were applied as immobilised enzyme on a support material, preferably selected from celite, silanised celite, alumina, silica, ion exchange resins, hydrophobic supports in particular polymerisation products from ethylene, or propylene, or styrene etc and most particular those known as EP 100 (an AKZO product).

However we found that the nature of the support used for the 1,3 specific enzyme used for the synthesis of the symmetrical triglyceride ABA from the 2-B monoglyceride had a high impact on both yield of the end product and on the purity of the endproduct ABA. Hydrophobic supports like EP 100 (ie a polypropylene support from AKZO) were found to give the highest yields of the purest ABA in the shortest times. Therefore we prefer to apply an 1,3 specific enzyme supported on a hydrophobic support for the conversion of the 2-B monoglyceride into the symmetrical triglyceride ABA. These hydrophobic supports are well known from eg our EP 322 213
Moreover we found that the highest yields of the purest products were obtained if the conversion of 2-B monoglyceride

was performed in the absence of a solvent.

The reactant providing the fatty acid moieties A that will react with the 2-B-monoglycerides can be selected from the group consisting of free fatty acids, alkyl esters of free fatty acids, in particular those with 1-6 C atoms in the alcohol part of the ester chain and in particular having an activated ester group and triglyceride. For the purposes of the invention it is a prerequisite that the triglyceride compounds have high contents of fatty acid residues A in the 1 and 3 positions. Typical examples of these components are palm top fraction (ie rich in P3), olive oil and other high oleic vegetable oils (ie rich in O3), cocoa butter fats (ie rich in C16/C18). However with the use of free fatty acids or their alkyl esters it is often easier to achieve the most optimal results.

Although the process can be performed in the presence of a solvent we found that the best results are obtained if a solvent is absent during the conversion. A very suitable solvent however, is the short alkyl ester of the free fatty acid that can also act as the source for the fatty acids A. Conveniently the conversion is performed using mole ratios monoglyceride : reactant providing fatty acid moiety A of 1:2 to 1:4.

The process is very well applicable for the production of the following triglycerides from the materials indicated, ie:

i)a 2-palmitate monoglyceride with an oleic acid source to prepare OPO rich fats.

ii)a 2-oleic monoglyceride with a source for C16 and/or C18 fatty acids to prepare SOS fats. (S= palmitic and/or stearic)

iii)a 2-saturated monoglyceride having either 10-14 or 16-24 C atoms in the fatty acid residue with a fatty acid source having either 16-24 or 10-14 C atoms to prepare symmetrical saturated triglycerides of the ABA type.

The compound with the high content of 2-B-monoglyceride can be made by a prior art process. This process comprises an alcoholysis of a triglyceride with a high percentage of B bonded in the 2-position, using a 1,3 specific enzyme in the presence of an organic solvent while maintaining the wateractivity during the conversion at 0.05-1.0, preferably 0.4-0.9. This process is known from Millqvist c.s. Enzyme Microb Technol 16 (1994) 1042-1047 and Biocatalysis 14 (1996) 89-111.

Again it was found that on the hydrolysis the nature of the support material for the enzyme had a high impact on the product composition. It was found that by using an enzyme on the same hydrophobic supports as mentioned above the highest yields of the purest 2-B monoglycerides could be obtained.

The 2-B-monoglyceride is isolated from the crude reaction mixture by crystallisation at a suitable temperature, ie low enough to achieve the desired results, such as T < -10 oC, for 2-unsaturated monoglycerides.

The organic solvent that is applied is selected from the group consisting of hydrocarbons, preferably having 4-12 C atoms, ethers, in particular having at least one branched alkyl residue, ketones, in particular acetone and alcohols.

The alcoholysis is in particular performed in a reaction system with a mole ratio triglyceride : alcohol of 1:5 to 1: 20.

EXAMPLES

MATERIALS AND METHODS

Lipase. Lipases (triacylglycerol lipases, EC 3.1.1.3) were from *Rhizopus delemar* (RDL), *Rhizopus javanicus* (RJL) (both from Amano Pharmaceutical Co. Ltd, Nagoya, Japan) and from *Rhizomocor miehei* (RML) (Biocatalysts Ltd, Pontybridd, England). One commercial lipase from RML (Lipozyme IM), immobilized on anion exchange resin, was from Novo (Bagsvaerd, Denmark). All chemicals and solvents used were reagent grade and purchased from common commercial suppliers, except peanut oil (Vaselin Fabrik, Bonn, Germany), EP 100 (porous polypropylene particles, 200-400 µm) (Akzo, Obernburg, Germany), and Celite 545 (Fluka, Buchs, Switzerland).

Hydrolytic activity of lipase. The hydrolytic activity of lipases was measured with 5% (w/v) olive oil emulsion (pH 8.0) containing 2% (w/v) gum arabic at 37°C. 20 ml of the emulsified solution, 470 µl of $CaCl_2$ solution (22% w/v) and a known amount of immobilized lipase were mixed, and liberated fatty acids were titrated automatically with 0.01 N NaOH in order to maintain the pH constant at pH 8.0. One unit (U) of lipase activity was defined as the amount of enzyme, which liberates 1 µmol fatty acid per min under assay conditions.

Immobilization of lipase. Celite 545 and EP 100 were used as supports for adsorptive immobilization of commercial lipases. Before immobilization, celite was washed several times with purified water and ethanol (95% v/v) to remove fines, and dried at 80°C. Then the pre-washed celite was mixed with 5% HNO_3 and stirred at 80°C for 4 hours. The acid-washed celite was carefully washed with purified water until the pH of the water was neutral and was then dried overnight at 80°C. One gram lipase powder was dissolved in 20 ml phosphate buffer (pH 7.0, 20 mM). The solution was added to 1.5 g acid-washed celite or EP 100 stirred at 5°C for 8 hours followed by addition of 5 ml chilled acetone (-15°C). The immobilized lipase was collected by filtration, washed three times with phosphate buffer (pH 7.0, 20 mM), dried at room temperature under vacuum for 48 hours and stored at 5°C until use.

1. Alcoholysis of triacylglycerides

Triolein (99%) or trilinolein (99%) (both 0.28 M) dissolved in methyl *tert*-butyl ether (MTBE) (2 ml) was equilibrated to water activity of 0.75 over saturated NaCl in a closed vessel. Dry ethanol was added to a final concentration of 2.8 M. The reaction mixture was incubated at 40°C in a stirred oil bath for 15 min, then the reaction was started by addition of 60 mg of immobilized lipase from RML, RDL or RJL, pre-equilibrated at water activity 0.11 over saturated LiCl. The reaction was stopped after 30 hours by removal of immobilized lipase. After evaporation of excess solvent *in vacuo*, the oily residue was dissolved in 20 ml *n*-hexane:MTBE (70:30 v/v) and stored at -25°C overnight. After this period, white crystals formed, which were collected by filtration at -25°C. The supernatant containing ethyl esters, diacylglycerides (DG), fatty acids and a small amount of TG was discarded. The 2-MG was recrystallized several times until the TLC plate showed only one band of 2-MG. Yields given in Tables 1 and 2 are percentages of the theoretical yield of 33.3 %. The purity of 2-MG was confirmed by NMR spectroscopy.

1)

Table 1

Synthesis of 2-monoolein (2-MO) by alcoholysis of triolein with ethanol in MTBE with lipases immobilized on Celite			
Lipase from	Initial rate (μmol/h/mg)	Initial rate (μmol/h/U)	Yield (%)
Rhizomucor miehei	0.56	2.23	40.5
Rhizopus delemar	0.65	0.30	71.8
Rhizopus javanicus	0.82	0.25	56.9

Table 2

Influence of triacylglyceride on the synthesis of 2-MG by alcoholysis with immobilized lipase from *Rhizopus delemar* in MTBE and ethanol.		
Triglyceride	Initial rate (μmol/h/U)	Yield (%)
Triolein	0.30	71.8
Trilinolein	0.41	60.6

2. Esterification reaction

The purified 2-MO obtained by alcoholysis in example 1 (60 mM) and caprylic acid (180 mM) were dissolved in 2 ml of *n*-hexane equilibrated to a water activity of 0.11. The reaction was started by addition of 12% (based on the weight of 2-M0) of different immobilized lipases **(water activity 0.11)** and 0.5 gram molecular sieve (4 Å). An aliquot of the reaction medium was applied to a Kieselgel 60 plate, which was developed in a mixture of *n*-hexane:diethyl ether:acetic acid (70:30:1.5). The components of the reaction mixture were visualized by spraying with 50% (v/v) sulfuric acid (dissolved in methanol), and heated at 150°C.

Purification of produced TG

The reaction mixture was purified by column chromatography. Silica gel (10g) and aluminium oxide (10g) were mixed in 50 ml *n*-hexane to make a slurry, which was poured into the column (300 mm x 30 mm). The reaction mixture (1g) containing DG, fatty acids and produced TG was applied to the column. The column was eluted with a mixture of *n*-hexane:diethyl ether (95:5 v/v). The recovered fractions were analysed by TLC.

HPLC separation of triacylglycerols

The composition of the triacylglycerols formed during the enzymatic esterification and interesterification was char-

acterised by HPLC using a nucleosil C_{18} column, (5µm, 250 x 4 mm, Sykam, Gilching, Germany) and an evaporative light scattering detector (S.E.D.E.R.E, Vitry/Seine, France) at a column temperature of 38°C and a flow rate of 1.0 ml/min. Elution was performed using a linear gradient elution system of 80% acetonitrile to 90% dichloromethane over 40 min. The extent of reaction was calculated from the molar or weight percentage of produced triacylglycerides present in the mixture. The results are given in Table 3.

2)

Table 3

Synthesis of structured triacylglyceride by esterification of 2-MO with caprylic acid (1:3 molar ratio) in *n*-hexane with different immobilized lipases.					
Lipase	Support	Initial rate [µmol/h/U]		Concentration of TG [wt%]	
		MLM	MLL	MLM	MLL
RML	Resin	70.6	3.7	89.1	8.8
RDL	EP 100	3.1	<0.1	91.2	8.0

EXAMPLE 3

Alcoholysis of triglycerides to yield 2-palmitic monoglycerides

Tripalmitin (=palm top fraction) was subjected to alcoholysis using Rhizopus Delamar (from Amano, Nagoya, Japan) in acetone. The water activity was maintained at about 0.43. The reaction was performed as described before in example 1 except that acetone was applied as solvent and EP 100 was applied as support for the enzyme. The product (2-palmitic monoglyceride) was obtained in a yield of 90 % and had a purity of >95 %.

EXAMPLE 4

Esterification of 2-palmitic monoglyceride

The 2-palmitic monoglyceride of example 3 was converted with oleic acid in a mole ratio of 1:3 using Rhizopus delamar on either Celite or on EP 100 as support material. Water formed during the conversion was removed in vacuo. The reaction was performed in the absence of a solvent (for the EP 100) or in the presence of n-hexane (in case Celite was applied as support).
The following results were obtained:

support	solvent	time	yield	P in 2 position of product OPO
Celite	hexane	24 hr	72%	94
EP 100	no	16 hr	78%	95.9

Claims

1. Process for the preparation of triglycerides of the ABA type, wherein A = saturated or unsaturated or polyunsaturated fatty acid residue with 2-24 C atoms and B = saturated or unsaturated or polyunsaturated fatty acid residue, while A is not simultaneously identical with B in the same molecule by:
subjecting a compound with a high content of, preferably more than 80 % of, most preferably more than 90 % of 2-monoglyceride with a group B substituted at the 2 position to an enzymatic conversion with a reactant providing fatty acid moieties A using a 1,3-specific enzyme under conditions that control the water activity Aw to a value < 1.0, in particular 0.1-0.5.

2. Process according to claim 1, wherein the 1,3 specific enzyme is selected from the group consisting of Rhizopus species, preferably Rhizopus delemar, Rhizopus javanicus or Rhizomucor meihei.

3. Process according to claims 1-2 wherein the enzyme is supported on a hydrophobic support material, preferably a polyethylene or polypropylene material.

4. Process according to claims 1-3, wherein the Aw is controlled by removal of the water formed during the enzymatic conversion, in particular by removal at elevated temperature at reduced pressure and/or adsorption of water by an absorbent in particular by a molecular sieve.

5. Process according to claims 1-4, wherein the reactant providing the fatty acid moieties A is selected from the group consisting of free fatty acids, alkyl esters of free fatty acids, in particular those with 1-6 C atoms in the alcoholic residue and triglycerides.

6. Process according to claims 1-5, wherein the process is performed in the presence of alkyl esters of the fatty acids that can act as reactant.

7. Process according to claims 1-6, wherein a mole ratio monoglyceride : reactant providing fatty acid moiety A of 1:2-1:4 is applied.

8. Process according to claims 1-7, wherein one of the following conversions is performed:

   i)a 2-palmitate monoglyceride with an oleic acid source to prepare OPO rich fats.
   ii)a 2-oleic monoglyceride with a source for C16 and/or C18 fatty acids to prepare SOS fats.
   iii)a 2-saturated monoglyceride having either 10-14 or 16-24 C atoms in the fatty acid residue with a fatty acid source having either 16-24 or 10-14 C atoms to prepare symmetrical saturated triglycerides of the ABA type.

9. Process according to claims 1-8, wherein the compound with the high 2-B-monoglyceride content is obtained by enzymatic alcoholysis of a triglyceride with a high percentage of B bonded in the 2-position, using a 1,3 specific enzyme in the presence of an organic solvent while maintaining the water activity during the conversion at 0.05-1.0, preferably 0.4-0.9.

10. Process according to claim 9 wherein the enzyme applied for the hydrolysis is supported on a hydrophobic support material, preferable being a polyethylene or polypropylene material.

11. Process according to claim 9, wherein the 2-B monoglyceride product formed is isolated from the crude reaction mixture by crystallisation at < -10 oC.

12. Process according to claim 9, wherein the organic solvent is selected from the group consisting of hydrocarbons, ethers, ketones, alcohols.

13. Process according to claim 9, wherein the alcoholysis is performed on a reaction system with a mole ratio triglyceride: alcohol of 1:5-1:20.